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The Effects of a Set Circuit Weight Training Program on Strength and Muscular Endurance of College Age Men

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THE EFFECTS OF A SET CIRCUIT WEIGHT

TRAINING PROGRAM ON STRENGTH

AND MUSCULAR ENDURANCE

OF COLLEGE AGE MEN

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Significant increases in 1 repetition maximum (1 RM) strength and absolute endurance resulted from participation in the set circuit weight training program. College age males (N = 42) enrolled in weight training classes participated in the study. Pre- and post-tests for 1 RM strength, absolute muscular endurance and relative muscular endurance were given for the bench press and leg press. Treatment consisted of 2 workout sessions per wk continuing for 7 wks. Each session, S(s) were required to complete 2 sets of 10 exercises. Both sets of an exercise were completed before a S moved to the next activity. A work/rest ratio of 20 sec/10 sec was used. Test-retest procedures and pre- and post-test mean changes were analyzed using Pearson r and dependent t analyses. Mean changes between pre- and post-tests for 1 RM strength in the bench press and leg press, absolute muscular endurance in the bench press and leg press and relative muscular endurance in the bench press were sig ($p < .05$). Non sig changes were found for the test of relative muscular endurance in the leg press ($p < .05$).

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CHAPTER I

INTRODUCTION

Significance of the Study

Numerous studies have been conducted on various weight training systems and their effects upon strength, muscular endurance and cardiovascular endurance (Foss, 1960; Gettman, et al, 1978; MacDougall, 1973; Conner, 1975; Mathews and Fox, 1976; Hoseth, 1967; Delateur, 1968; O'Shea, 1966; Hansen, 1969; Wilmore, et al, 1978; and DeLorme, 1952). These studies and the resulting programs formulated from them are of special concern to athletes and their coaches. Of particular concern is the in-season weight training program designed for maintenance of strength and increased muscular endurance. Time limitations in practice schedules continue to be a problem that have always restricted the use of prescribed weight training programs during practice sessions. Circuit weight training workouts, which require less time to complete than traditional systems of weight training, have helped reduce this problem. In circuit weight training, exercises are selected and arranged in an order that will minimize fatigue. This implies that exercises involving similar muscle groups or body parts are separated in the circuit, consequently a subject can perform each exercise with minimal rest between activities without experiencing fatigue. In circuit weight training, one set of an exercise is completed before the subject moves on to the next activity. After one circuit is complete, the subject can repeat the circuit one or two more times. Since each set of an exercise is performed just once in a circuit, the muscles involved in that exercise will have a sufficient chance to rest before the exercise is repeated.

Studies show that circuit weight training programs do enhance one or more of the following areas: strength, muscular endurance and cardiovascular endurance (Foss, 1960; Gettman, et al, 1978; Conner, 1975; MacDougall, 1973; Wilmore, et al, 1976; and Wilmore, et al, 1978). It is the purpose of this investigation to study the effects on strength and muscular endurance of one specific weight training program, hereafter called the set circuit program. Unlike a regular circuit program, the set circuit program requires all sets of an exercise to be completed before the subject moves to the next activity. The set circuit program, like other circuit programs, allows minimal rest between sets and exercises. By doing all sets of an exercise before moving on to the next activity, the overload principle can be applied immediately to the muscle groups involved in that exercise (Hellebrandt, 1958; DeLorme, et al, 1952; and Cratty, 1973). The overload of the muscles is achieved by allowing insufficient rest time for muscle recovery, thus maximizing fatigue of the muscles which enhances their strength and muscular endurance (Clark, et al, 1954; Homola, 1969; Morehouse and Rasch, 1958; and Karpovich, 1965). Though all circuit programs do allow rest between exercises, the rest time allowed by the set circuit program is less than that of many other programs which reduces the total workout time required.

Statement of the Problem

The purpose of this study was to observe the effects of a set circuit weight training program on strength and muscular endurance of college age men.

Hypotheses

The following are listed as hypotheses for this study:

1. It was hypothesized that there would be a significant increase in one repetition maximum (1 RM) strength in the bench press and leg press exercises using the set circuit weight training program following a seven-week training session.

2. It was hypothesized that there would be a significant increase in absolute muscular endurance for the bench press and leg press exercises using the set circuit weight training program following a seven-week training session.

3. It was hypothesized that there would be no significant increase in relative muscular endurance for the bench press and leg press exercises using the set circuit weight training program following a seven-week training session.

Scope

Participants in the study were 42 male college age students enrolled in weight training classes at South Dakota State University in the fall semester of 1979. All subjects were assigned the set circuit training program. Training sessions were held two days a week continuing for seven successive weeks. A strength pre-test was given to determine one repetition maximum strength (1 RM) in the bench press and leg press exercises. An endurance pre-test followed measuring absolute muscular endurance using a modified version of Hoseth's (1967) test for muscular endurance. The pre-tests were repeated on the following day of training to determine reliability. A treatment period followed in which all subjects used the same number of sets, repetitions and exercises. Post-tests were given following the treatment to measure 1 RM strength, absolute muscular endurance and relative muscular endurance in the bench press and leg press exercises. Post-tests were repeated on the following day of training to determine reliability.

Limitations

The writer realizes that the following were limitations of the study:

1. The subjects' training activities could not be controlled outside of the test situation.

2. The motivation of each subject to put forth a maximal effort could not be controlled during the test and treatment sessions and may vary for each subject from session to session.

3. Accuracy of the 1 RM strength measurements was limited to the weight intervals on the instrument of measurement (universal gym).

4. The study was limited to 42 college age males enrolled in weight training classes at South Dakota State University. All 42 participated in the treatment, pre- and post-tests. The results for all 42 subjects in the bench press exercises were used for analysis. The investigator was unable to determine the 1 RM strength in the leg press for four subjects due to a fixed upper limit on the leg press exercise. Scores for these four individuals were not used for analysis of the leg press exercises.

Terminology

The following terms or phrases are special to the study and need explanation as follows:

Absolute Muscular Endurance. Absolute muscular endurance is defined as the total increase in muscular endurance gained by a subject, independent of the amount of strength gained during the same period. Pre- and post-tests for measuring absolute muscular endurance use a fixed resistance during the administration of both tests. That is, the resistance is the same for both tests.

One Repetition Maximum. One repetition maximum (1 RM) is defined as the maximum amount of resistance a subject can move through a range of motion one time.

Relative Muscular Endurance. Relative muscular endurance is defined as the increase in muscular endurance, if any, gained by a subject, dependent upon the amount of strength gained during the same period. The pre- and post-tests for measuring relative muscular endurance use a percent of the 1 RM rather than a fixed weight. The resistance used for pre- and post-tests may vary.

Set Circuit. A set circuit program is defined as a circuit program in which the subject does all sets of an exercise before moving to the next station.

CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of this study is to observe the effects of the set circuit weight training program on strength and muscular endurance of college age men. The review of literature consists of an investigation into the following areas:

1. Definition and methods of measuring muscular endurance.
2. Physiological changes within the muscle to attain strength and muscular endurance.
3. Training methods used to induce strength and muscular endurance.
4. Selected weight training programs and their effects on strength and muscular endurance.

Definition and Methods of Measuring Muscular Endurance

Muscular endurance has been defined as the ability to continue muscle exertions of submaximal magnitude (Clarke, 1967). Muscular endurance has also been defined as the ability of a muscle group to perform repeated contractions against a light load for an extended period of time (Mathews and Fox, 1976). Yet another definition is the ability to resist muscular fatigue and persist in a physical activity (Hoseth, 1967). All these definitions produce basically the same meaning, that is, muscular endurance is the ability of a muscle or muscle group to contract repeatedly against a resistance that is not maximal.

In order to measure muscular endurance, an attempt must be made to isolate muscle groups. Little standardization of procedure and formation of comprehensive norms is available (Clarke, 1975). Thus, tests for measuring muscular endurance have applied the definition, that is, repeated motion with a submaximal load.

The most common test for measuring muscular endurance is the arm lever ergometer (Clarke, et al, 1970; Scotland, 1976; Shaver, 1970; Shaver, et al, 1973; and Stull, et al, 1970). It is possible to isolate individual muscle groups for testing purposes with the arm lever ergometer. Since it can be used to administer treatments as well as tests, the arm lever ergometer is very practical for lab situations. Studies using the ergometer were limited to observation of a specific muscle group.

Another test for measuring muscular endurance was developed for weight training studies by having subjects repeatedly perform a weight training exercise until fatigued (Hoseth, 1967). Using this testing method, individual muscle groups may be harder to isolate for examination purposes. However, this method employs tests that are similar to weight training exercises used in the treatment. Therefore, the test results achieved using this testing method may be more indicative of the gains produced by a weight training program.

The interest in this investigation lies in the changes found in strength and muscular endurance for several muscle groups due to training with the set circuit program. Treatment for this study was given by way of weight training exercises on the universal gym and mini-gym leaper. A modified version of Hoseth's test for measuring muscular endurance was employed for the pre- and post-tests. This method was chosen because the pre- and post-tests were similar to the exercises used in the treatment and were more indicative of the results produced by the set circuit program.

One precaution was observed using this method. It was found that tempo or cadence of an exercise affects the amount of endurance gained, that is, a faster work rate will also cause a faster rate of fatigue. Thus, findings indicated that a constant cadence must be set if test results are to be valid (Hellebrandt, 1958).

Physiological Changes Within the Muscle to Attain Strength and Muscular Endurance

It is extremely difficult to completely separate the relationship between strength and muscular endurance. Each aspect of muscle performance, strength, endurance and speed seems closely related to the others (Hellebrandt, 1958). Studies show that increases in strength are also accompanied by increases in absolute muscular endurance (Clarke, *et al*, 1970; Stull, *et al*, 1970; Clarke, 1975; Hoseth, 1967; Shaver, 1970; Wilmore, *et al*, 1976; Homola, 1969; Hansen, 1969; Wilmore, *et al*, 1978; and DeLateur, *et al*, 1968). However, these increases are not necessarily proportional (Shaver, 1970; and Noble, 1973).

A change associated with increased strength and muscular endurance is that of hypertrophy. Hypertrophy of muscle fibers due to training has been an accepted fact for years (Gordon, 1967; Mathews and Fox, 1976; Goldspink, 1964; and Karpovich, 1965). Hypertrophy consists of an increase in diameter of muscle fibers that are exercised, bringing about an increased cross-sectional area of the individual fibers. Hypertrophy does not increase the diameter of all fibers. Rather, it increases the diameter of the smaller fibers to the size of the larger ones (Mathews and Fox, 1976; Goldberg, et al, 1975; Goldspink, 1964; and Karpovich, 1965).

Selected studies were reviewed which investigated causes for hypertrophy. The following areas were investigated:

1. Changes in the number of myofibrils per fiber.
2. Changes in the amounts of connective tissue.
3. Longitudinal splitting.
4. Specificity of training and fiber types.
5. Review of the biopsy literature.

Changes in the number of myofibrils per fiber. One of the physiological changes in the muscle contributing to hypertrophy is an increased number of myofibrils per fiber (Mathews and Fox, 1976). In an investigation with mice, it was found that a three to four-fold increase in myofibrils per fiber existed following training (Goldspink, 1964). It was noted that the myofibrils per fiber increased in a linear manner with the increase in fiber diameter. Contrary to these findings, results of another study indicated that the investigators were not able to determine a significant difference in the number of myofibrils per fiber between exercised and non-exercised rats. It was observed that the myofibrils in exercised rats varied greatly in size and distribution within the muscle fibers. The increase, however, was at the ends of the muscle rather than at the center (Holmes and Rasch, 1958).

Changes in amounts of connective tissue. Another change that is believed to contribute to hypertrophy is an increased amount of connective, tendinous and ligamentous tissue (Mathews and Fox, 1976). Tissues are strengthened and enlarged with training and muscle growth (Goldberg, et al, 1975).

Longitudinal splitting. Until recently, hypertrophy was attributed solely to an increase in the size of the diameter of a fiber. There is now some indication that longitudinal splitting may be another cause of hypertrophy (Mathews and Fox, 1976). The result of longitudinal splitting is an increased number of fibers which accompanies muscular growth of an hypertrophying muscle (Goldberg, et al, 1975).

Specificity of training and fiber types. Specificity of training programs and concentration of muscle fiber types have become important considerations in the development of an athlete. Energy systems used and movement patterns of the muscles involved in an activity are primary guides as to the type of training program that must be developed (Mathews and Fox, 1976; and Cratty, 1973). The kind of exercise and training used by a subject will determine if hypertrophy is to occur (O'Shea, 1966; Clarke, 1975; and Penman, 1970). Training with strength emphasis produces muscle enlargement and develops more contractile protein (actomyosin) per unit of muscle (Gordon, 1967). An increase in the myofibril portion of the muscle also enhances its ability to contract (Clarke, 1975). A change accompanying a hypertrophied muscle is a slowing of its contractile properties (Goldberg, et al, 1975). Training with endurance emphasis tends to elevate the energy liberating systems which develop increased sarcoplasmic protein and enzymes of the muscle cell (Gordon, 1967).

Of course, all types of training programs do not produce hypertrophy. Instead, an increased packing density of the contractile elements in the cell can result from training (Penman, 1970). Despite procedural differences between muscular endurance and strength training programs, there is evidence that these programs produce strikingly similar results (Hellebrandt, 1958).

Skeletal muscle of endurance athletes appears to have a predominance of slow twitch muscle fibers while the skeletal muscle of a power athlete tends to consist of fast twitch fibers (Thorstensson, et al, 1977; and Gollnick, et al, 1972). Difference of muscle types in athletes does not appear to be significant. A conclusion drawn from this investigation is the training effect on explosive strength could be attributed to something other than muscle fiber distribution (Thorstensson, et al, 1977). Both fiber types were found to be more developed in trained subjects (Gollnick, et al, 1972) while fiber distribution did not change due to training (Henriksson, 1977).

Review of the biopsy literature. There exist certain limitations in a study such as this concerning the development and improvement of muscle tissue through weight training. Such improvements should be studied through the use of biopsies from muscle tissue. The literature shows that studies using biopsies may be conducted with proper personnel, equipment and facilities. Due to the lack of adequate equipment, facilities and trained personnel for biopsy examination, this study was restricted to examining changes in muscle performance through selected exercises. Despite the fact the muscle biopsies were not taken in this study, the writer has chosen to include a review of several biopsy studies in the review of literature. These investigations serve as supplementary material to this study. Their findings indicated that many biochemical changes occur in muscle tissue due to training; thus, serve as possible reasons explaining the development of muscle tissue through the use of weight training.

The following areas were selected for the review of the biopsy literature:

1. Changes in capillary density.
2. Biochemical changes in muscle.

(1) Changes in capillary density. Endurance training has long been associated with increased capillary density per fiber (Mathews and Fox, 1976; and Karpovich, 1965).

Biopsies from the lateral portion of the quadriceps femoris were examined for capillary density. Findings indicated no significant difference in the number of capillaries per mm^2 between trained and untrained subjects. Average number of fibers per mm^2 was found to be 140 less in the trained subjects. Average size of a trained muscle cell was 30 percent larger. Number of capillaries per fiber was found to be larger in the trained (1.5 to 1) than in the untrained subject

(1 to 1). Increased size in the trained muscle cell and the increased number of capillaries per fiber account for the lack of change in the number of capillaries per mm^2 of the trained subjects (Hermansen and Wachtlova, 1971).

Biopsies were taken in a similar study from the lateral portion of the quadriceps femoris. It was found that the average number of capillaries per fiber was 41 percent greater in an endurance trained subject as compared to an untrained subject. Average number of capillaries around each fiber was found to be 33 percent greater in trained subjects. Results indicate that each capillary is shared by fewer fibers in a trained individual (2.34 $\pm$ 0.03) than in an untrained subject (2.50 $\pm$ 0.03). Contrary to previous results, it was found that the number of capillaries per mm^2 was 41 percent greater in the endurance trained individuals. Mean capillary per fiber ratios of trained to untrained subjects were 2.49 $\pm$ 0.08 and 1.77 $\pm$ 0.10. The number of capillaries around each fiber were 5.89 $\pm$ 0.18 and 4.43 $\pm$ 0.19. The number of capillaries per mm^2 was found to be 821 $\pm$ 28 and 585 $\pm$ 40. The number of capillaries per fiber increased with the increase in fiber diameter but not sufficiently to maintain the number of capillaries per mm^2. Fibers with many mitochondria were surrounded by more capillaries than fibers with few mitochondria. Fiber diameter increased in a linear manner with increases in the number of capillaries around each fiber. Increased fiber diameter may not necessarily cause increased capillary density since hypertrophy causes the fiber to take up a larger area. Results of the study indicate that oxygen extraction is increased by endurance training of the muscle (Brodal, et al, 1977).

Physical training increases muscular strength and improves efficiency of muscular activity. Training also increases capacity for sustained muscular work, decreases the onset of fatigue and improves oxygen transport (Bourne, 1960).

Biopsies taken from the vastus lateralis portion of the quadriceps femoris of subjects trained on a bicycle ergometer were examined. Results showed an increased capillary supply to the muscle as a whole due to endurance training. Biopsies revealed a 20 percent increase in capillary density and in mean fiber area following training. Capillary supply to both fiber types, that is, the mean number of capillaries in contact with each fiber, increased equally. It was concluded that endurance training is a powerful stimulus for capillary production in human skeletal muscles (Andersen, 1977).

(2) Biochemical changes in muscle. Six subjects trained one leg on a bicycle ergometer for a two-month period using the untrained leg as a control. The study indicated no significant difference in the oxidative capacities for the legs prior to training. After training, the muscle oxidative capacity, which was determined as succinate dehydrogenase activity, increased 27 percent in the trained leg. A major finding of this investigation indicated that the degree of fat combustion was higher in the trained leg. This finding appeared to be related with the higher oxidative capacity of the trained leg (Henriksson, 1977).

Biopsies were taken from the vastus lateralis and deltoid muscles of trained and untrained men. Succinate dehydrogenase was highest in the muscle groups of the endurance trained men. A minor difference was found to exist for phosphofructokinase (PFK) activity in muscles of trained and untrained subjects. Oxidative capacity for both fiber types was found to be higher in the trained subjects. Also, trained subjects were found to have the highest muscle glycogen stores (Gollnick, et al, 1973).

Again, biopsies were taken from the vastus lateralis muscle and examined. After five months of training on a bicycle ergometer, subjects showed increases of 95 percent in mean succinate dehydrogenase activity and 117 percent in phosphofructokinase activity. Oxidative potential of both fiber types increased and muscle glycogen content was 2.5 times higher after training. A conclusion drawn from the study indicates that an increase in PFK aids in the breakdown of glycogen to supply energy for muscle contraction (Gollnick, et al, 1973).

Needle biopsies taken from the triceps brachii of subjects were analyzed for biochemical changes following five months of heavy resistance training. Resting concentrations of creatine were up 39 percent, creatine phosphate up 22 percent, adenosine triphosphate (ATP) up 18 percent, and glycogen up 66 percent. It was concluded that heavy resistance training can give a biochemical advantage to a muscle by increasing its energy reserves (MacDougall, et al, 1977).

Endurance exercise will increase the capacity of a muscle to regenerate ATP aerobically (Clarke, 1975). Aerobic changes due to training are (Mathews and Fox, 1976):

1. Increased myoglobin content.
2. Increased oxidation of glycogen.
3. Increase in the number and size of the mitochondria in skeletal muscle fibers.
4. Increased concentration of enzymes involved in the Krebs Cycle and electron transport system.
5. Increased amounts of glycogen stored in the muscle.
6. Increased activity of glycogen synthetase.
7. Increased oxidation of fat which reduces lactic acid accumulation resulting in less fatigue.

Anaerobic changes due to training are (Mathews and Fox, 1976):

1. Increased capacity of the ATP-PC system.
2. Increased muscular levels of ATP, PC and creatine kinase.

A biopsy study was conducted using vastus lateralis muscles taken from subjects trained with isotonic, isometric and running techniques. Increased amounts of glycogen and intracellular fats, greater mitochondrial length, decreased myosin density and increased myosin fiber diameter were among the findings (Penman, 1969).

Biopsies of vastus lateralis muscles were taken from subjects who trained with isometric or isotonic programs for ten weeks. Examination of the biopsies revealed an increase in packing density of the contractile elements in the cell and a changing ratio of actin to myosin (Penman, 1970).

Skeletal muscle adapts to endurance exercise with an increased capacity of the mitochondrial fraction of the muscle to oxidize pyruvate and long chain fatty acids. Along with the improved ability to obtain energy by respiration, endurance exercise produces increased levels of mitochondrial enzymes. An increase in mitochondrial enzymes appears to be due to an increase in enzyme protein. Results of training produced a 60 percent increase in the protein content of the mitochondrial fraction of skeletal muscles and a doubling of the concentration of cytochrome c. Increased size and number of mitochondria are in turn responsible for the increase in mitochondrial protein. The main change due to muscular endurance exercise is an increase in the capacity for aerobic metabolism (Holloszy, 1975).

Gastrocnemius muscles of rats subjected to strenuous treadmill running were examined. Capacity of the mitochondrial fractions to oxidize pyruvate doubled during training. Succinate dehydrogenase, succinate oxidase, cytochrome oxidase activities and concentrations of cytochrome c increased two fold in response to training. Total protein content of the mitochondrial fractions increased 60 percent. Results of strenuous work showed an increase in the aerobic work of the muscles as compared to mild exercise which showed no effect on biochemical changes in the muscle (Holloszy, 1967).

After 18 weeks of training guinea pigs on a treadmill, the mitochondrial protein concentration per gram of muscle increased significantly in the trained animals (4.10 to 5.32 mg/g). Findings indicated that low resistance exercise increased the mitochondrial and oxidative capacities (Barnard, et al, 1970).

Training Methods Used to Induce Muscular Endurance

The overload principle has become the basis for many training programs today (Scotland, 1976; MacDougall, 1973; DeLateur, et al, 1968; Noble and McCraw, 1973; McMorris and Elkins, 1954; and DeLorme, et al, 1952). It is believed that the application of this principle is necessary to improve performance (Hellebrandt, 1958; DeLorme, et al, 1952; and Cratty, 1973). Theory behind the overload principle is to force the muscle to contract repeatedly at levels of performance which strain the limits of capacity. The result of using this principle is hypertrophy. As a muscle develops, stress must be increased at a progressive rate. Discomfort of the muscle is associated with the use of this principle. Progressive increases in a program using the overload principle can be implemented by using an increase in resistance (weight or repetition) or by an increase in speed (cadence) (Hellebrandt, 1958; Clarke, et al, 1970; Mathews and Fox, 1976; and Karpovich, 1965). Training by use of the overload principle has produced dramatic gains in strength, power, muscular endurance and work done, while underload training has shown minimal gains (Hellebrandt, 1958; and Mathews and Fox, 1976). Despite significant gains in absolute endurance, there have been no significant gains demonstrated in relative endurance using the overload principle (Shaver, 1970; Stull and Clarke, 1970; and Clarke and Stull, 1970).

Selected Weight Training Programs
and Their Effect on Strength and
Muscular Endurance

Strength and muscular endurance can be increased by programs that are of high resistance and low repetition or low resistance and high repetition (Mathews and Fox, 1976). As long as the overload principle is applied in a program, it will improve strength and muscular endurance (Hellebrandt, 1958).

Comparisons of three selected training programs were made in which resistance and repetition were varied. All three showed significant increases in mean strength with no significant difference between the groups (O'Shea, 1966). Increased strength also increased work capacity which in turn leads to an increase in muscular endurance (Noble and McCraw, 1973; Shaver, 1970; and Hellebrandt, 1958).

Significant increases in both strength and muscular endurance were found in studies using a circuit program (Wilmore, et al, 1976), isotonic-isometric and isometric-isotonic programs (Hoseth, 1967) and isotonic programs (Noble and McCraw, 1973).

Summary

A close relationship exists between strength and muscular endurance. Increases in one of these areas is often accompanied by an increase in the other. This close tie between these two areas of muscular development has created some difficulty in measuring muscular endurance. It has become practice in studies involving measurement of muscular endurance to apply the definition of muscular endurance to the tests being used. Muscular endurance is the ability of a muscle group to perform repeated contractions against a submaximal load. This implies that tests used to measure muscular endurance use repeated motion against a resistance that is less than maximal. The tests used to measure muscular endurance are also similar to the treatments used to develop the muscles, thus adding validity to the results of the studies.

There are numerous changes that occur within the muscle during training to improve strength and muscular endurance. One of these changes associated with muscle training is hypertrophy. Hypertrophy is an increase in muscle size usually caused by an increase in the diameter of the fibers that constitute the muscle. There is some indication that hypertrophy may also be caused by longitudinal splitting of the muscle fibers. This splitting increases the total number of fibers which in turn increases the muscle size. Increased amounts of connective, tendinous and ligamentous tissues due to training also contribute to hypertrophy.

An increase in the number of myofibrils per fiber is another change that is associated with muscle development during training. Increases in myofibrils take place at the ends of the muscle rather than at the center.

Increased capillary density has been associated with muscle development through endurance training. In addition, increased size in capillaries, increased number of capillaries per fiber and increased number of capillaries around each fiber were found.

There exists numerous biochemical changes that take place in the muscle due to training. The oxidative capacity and glycogen stores are higher in trained than in untrained subjects. Increased protein and protein synthesis, increased mitochondrial proteins and enzymes, and increased size and number of mitochondria were found to be results due to training.

Considerations that have become important in the development of training programs are specificity of training and concentration of muscle fiber types. The kind and extent of training used by a subject will determine if strength, muscular endurance and hypertrophy are to occur. All muscle fiber types can be developed through training, but their distribution does not appear to be affected.

All of today's training programs use the overload principle as the basis for development. Muscles must be forced to contract repeatedly at levels of performance which strain the muscle if improvements in strength and muscular endurance are to be made.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this investigation was to observe the effects of a specific circuit weight training program on strength and muscular endurance of college age men. In this chapter the procedures involved are described in the following sections:

1. Organization of the study.
2. Source of data.
3. Collection of the data.
4. Administration of the treatment.

Organization of the Study

Weight training classes consisting of 42 college age males at South Dakota State University were used as subjects for the study. The subjects were divided into three groups according to pre-existing class schedule assignments with each group assigned the same weight training program, testing procedures and administration of treatment.

Instruction sheets for pre- and post-tests were given to all subjects and explained prior to testing. All tests were given on the universal gym. All treatments were given on the universal gym and mini-gym leaper.

A pre-training period of four weeks was conducted prior to pre-testing and administration of treatment. This period utilized exercises that were the same as those used in the treatment section. All subjects were given a partner and together they went through the entire workout. The order in which the exercises were done varied from session to session as well as the amount of rest taken by a subject between sets and exercises.

Several reasons for a pre-training period were found in the literature. A primary purpose of the pre-training period was to familiarize the subjects with the proper technique involved in weight training. Instructions were given to the subjects pertaining to the procedures to be used for each exercise.

The literature indicated another purpose for the pre-training period concerning the subjects' need to adjust their balance and coordination in applying the proper lifting techniques (Morehouse and Rasch, 1958). With the improvement in technique, balance and coordination, a subject is able to handle more weight after a few practice sessions than was initially possible. These initial increases in weight are due to learning correct lifting procedures and adjusting body position to best suit the exercise. They are accomplished without increases in strength. In other words, fundamental processes in weight lifting require a great deal of skill. A pre-training period allows the subjects to acquire this skill (Massey, et al, 1971). Accompanying this increase in skill and technique is the reduction of the possibility of injury. As a subject becomes more proficient with proper lifting technique, the possibility of obtaining an injury is diminished.

The development of the general musculature is important to attain prior to involvement in a strenuous lifting program (Hooks, 1962).

Therefore, overall body development is another goal of the pre-conditioning period (Massey, et al, 1971). This aspect of the pre-training period should aim at strengthening and conditioning the general musculature as well as helping to build cardiovascular endurance (Dobbins and Sprague, 1978).

A final purpose for the pre-training period was to help determine the proper amount of weight to be used for each exercise. The most often used and suggested method is simply that of trial and error (Massey, et al, 1971; Morehouse and Rasch, 1958; Hooks, 1962; and Dobbins and Sprague, 1978).

Source of Data

Subjects for this study were 42 volunteer male members of weight training classes at South Dakota State University enrolled for the 1979 fall semester. Each subject's physical characteristics appear in Table I describing age, height, weight and percent body fat.

Collection of the Data

Pre- and post-tests for all subjects were given to determine 1 RM strength in the bench press and leg press exercises. Tests were repeated during the next session. 1 RM strength was determined by the maximum amount of resistance a subject can move through a complete range of motion one time for that exercise. For the 1 RM strength tests, the subjects were divided into groups of five. The first subject of the group assumed a correct position for that exercise and completed his lifting for the first set. When the first subject was

TABLE I

PHYSICAL CHARACTERISTICS OF SUBJECTS (N = 42)

	Age (yrs)	Ht (cm)	Wt (kg)	% Body Fat
$\overline{X}$	18.7	179.2	79.0	14.6
SD	1.4	7.0	12.8	6.7
Range	18-24	167.0-195.5	53.0-195.5	8.3-37.8

finished, he removed himself from the exercise station and the second subject of the group assumed a correct position for that exercise. The second subject completed his first set of the exercise and removed himself from the exercise station. This procedure continued until all five subjects completed their first set. The first subject again assumed the correct position for the exercise and completed his second set. The rotation of subjects continued until all five had completed their second set. The subjects continued to use this rotational procedure until all subjects found their 1 RM strength for that exercise. A lifting warm-up of three to four sets is recommended prior to a subject's attempt at a maximum lift (Homola, 1969). Following this procedure, the first set for all subjects was a warm-up set consisting of three repetitions at the resistance the subject had been using for that exercise in the pre-training or treatment workouts. The second and third sets were also warm-up sets consisting of three repetitions at a resistance that was 10 to 25 pounds greater than the resistance used for the previous set. The fourth set and any successive sets were maximum lifting sets consisting of one repetition at a resistance that was 10 to 25 pounds greater than the resistance used for the previous set. The rotation of subjects through the sets continued until all subjects of a group found their 1 RM strength for that exercise.

It has been suggested that a subject needs sufficient rest time between sets in order for his muscles to recover. A study on strength decrement following exhaustive exercise found that 30 seconds after that exercise, a subject suffered a 29 to 33 percent drop from pre-exercise strength levels. During the next two minutes, strength levels increased to the level of a 21 percent loss from pre-exercise strength. At this point, the rate of strength gradually increased at a decelerated rate of recovery for an additional ten minutes (Clarke, et al, 1954). A minimum rest of one minute between sets is suggested (Homola, 1969) with a maximum rest of three minutes following exhaustive exercise (Morehouse and Rasch, 1958; and Karpovich, 1965). Rest longer than three minutes does not show significant increases in recovery of strength, while rest periods less than one minute do not allow sufficient recovery of the muscle. Since the warmup sets were not maximal lifts or exhaustive exercise, a rest period of one to three minutes should have been sufficient for muscle recovery during the 1 RM strength tests.

All subjects, using Hoseth's method for testing muscular endurance, were pre- and post-tested for absolute muscular endurance and post-tested for relative muscular endurance. The resistance used for the pre- and post-tests for absolute muscular endurance was 70 percent of the results found for the pre-test 1 RM strength in the bench press exercise and 80 percent of the results found for the pre-test 1 RM strength in the leg press exercise. The resistance used in the post-test for relative muscular endurance was 70 percent of the results found for the post-test 1 RM strength in the bench press and 80 percent of the results found for the post-test 1 RM strength in the leg press. A cadence of approximately one repetition per two seconds was used for both exercises. Using a watch, the cadence was monitored by the tester, who informed the subject to increase or decrease his pace when necessary.

The subjects were required to perform as many complete repetitions of an exercise as possible. At no time during the test was the subject allowed to rest or pause. When the subject could no longer complete a repetition, the test stopped. The number of repetitions successfully performed was recorded as the subject's score. All pre- and post-tests were repeated during the next training session to help determine reliability. The highest score of the two tests was used as the measure of 1 RM strength, absolute muscular endurance or relative muscular endurance.

Administration of the Treatment

Treatment for all subjects consisted of two training sessions per week continuing for seven weeks. All subjects did the following exercises in the order in which they are listed:

1. Bench Press
2. Leaper
3. Leg Press
4. Hamstring Curls
5. Curls
6. Tricep Pulldowns
7. Upright Rowing
8. Lat Pulls
9. Military Press
10. Sit-ups

All subjects did two sets of each exercise before moving on to the next station. Subjects did 12 repetitions for the first set of each exercise and 10 repetitions for the second set. Resistance was adjusted for each individual so that the last two or three repetitions of each set were difficult to finish. It may have been necessary for the subject to decrease the resistance for the second set in order to finish all 10 repetitions. A time period of 20 seconds was given to complete each set of exercises. The subject was to pace his work rate so as to use the entire work period to finish his set of exercises (approximately 1 repetition/2 seconds). A 10-second rest period was given following each 20 second work interval. During the rest period, the subject was allowed to reduce the resistance for the second set of an exercise or move on to a new exercise.

No control groups were used in the study. Previous investigations have indicated that increases in strength and muscular endurance occur when weight training programs apply the overload principle. Increases in strength and muscular endurance are expected to occur. The purpose of this study was to find the extent that the training program had on changes found in the investigation.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

The purpose of this study was to observe the effects of a specific circuit weight training program on strength and muscular endurance of college age men. The findings of this investigation are presented in this chapter as follows:

1. Organization of the data for analysis.

2. Analysis of the data.

3. Summary of the findings.

Organization of the Data for Analysis

The assessment of 42 college age males enrolled in weight training classes during the fall semester at South Dakota State University produced the results for this study. The following measures were used in the investigation for the bench press and leg press exercises:

1. One repetition maximum (1 RM) strength.

2. Absolute muscular endurance.

3. Relative muscular endurance.

Statistical procedures were processed by use of the Statistical Package for Social Sciences (SPSS). The procedures used to analyze the data were as follows:

1. Measures of central tendency to describe the data.

2. Pearson product moment correlation coefficient to determine reliability.

3. Dependent t-test to determine if mean differences exist between test-retest and pre- and post-test scores.

The variables of height, weight, percent body fat, 1 RM strength, absolute muscular endurance and relative muscular endurance were analyzed for significant changes between test-retest procedures. The variables of 1 RM strength, absolute muscular endurance and relative muscular endurance were analyzed to determine mean changes between pre- and post-tests.

Analysis of the Data

The analysis of the data is covered in the following sections.

1. Reliability and reproducibility of anthropometric measures.
2. Reliability and reproducibility of neuromuscular measures.
3. Mean changes in neuromuscular measures following treatment.

All statistical procedures were conducted according to those outlined by Morehouse and Stull (1975).

Reliability and reproducibility of anthropometric measures. Anthropometric measures of height, weight, and percent body fat were taken on two separate days. To determine reliability, the Pearson product moment correlation coefficient was used to analyze the test-retest procedures for the anthropometric data. The dependent t-test was used to determine the reproducibility of this data (Table II). The analysis of height, weight and percent body fat test-retest results all produced perfect positive correlations (r = 1.00). The dependent t-test, used to determine reproducibility for the test-retest

TABLE II

RELIABILITY AND REPRODUCIBILITY OF ANTHROPOMETRIC TESTS (N = 42)

	Day 1 (Pre)		Day 2 (Pre)					
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}\Delta$	SE Δ	t	r
Height[a]	179.2	7.0	179.2	6.9	0.0	0.0	-0.53	1.00
Weight[b]	79.0	12.8	79.0	12.8	0.0	0.1	0.29	1.00
% Body Fat	14.5	6.7	14.6	6.6	0.1	0.1	0.90	1.00

[a]centimeters

[b]kilograms

procedures of the anthropometric data, produced nonsignificant t-ratios for the variables of height, weight and percent body fat.

Reliability and reproducibility of neuromuscular measures. Pre-tests were given on two separate days in the areas of 1 RM strength and absolute muscular endurance for the bench press and leg press exercises (Table III). Similarly, post-tests were given to the subjects on two separate days following treatment in the areas of 1 RM strength, absolute muscular endurance and relative muscular endurance in the bench press and leg press exercises (Table IV). The reliability of both the pre- and post-tests was determined by using the Pearson product moment correlation coefficient. The 1 RM strength pre-test for the bench press yielded the highest correlation coefficient ($r = .96$). The other pre-tests were found to have high test-retest correlation with the absolute muscular endurance tests for the bench press and leg press and the 1 RM strength test for the leg press all producing the same results ($r = .90$).

Test-retest correlation for the post-tests were as follows: 1 RM strength tests for the bench press and leg press had the highest correlations ($r = .96$). These were followed by coefficients for the test for absolute muscular endurance for the bench press ($r = .94$), the test for absolute muscular endurance for the leg press ($r = .92$), the test for relative muscular endurance for the leg press ($r = .91$), and the test for relative muscular endurance for the bench press ($r = .89$).

Reproducibility of the test-retest method was analyzed using the dependent t-test. Pre-tests in 1 RM strength for the bench press and

TABLE III

RELIABILITY AND REPRODUCIBILITY OF NEUROMUSCULAR PRE-TESTS

		Day 1		Day 2					
Test	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}\Delta$	SEΔ	t	r
1 RM Strength[d]									
Bench Press	42	149.9	25.4	149.6	28.0	-0.3	1.2	-0.20	.96
Leg Press	38	417.9	61.8	419.2	60.0	1.3	4.5	0.29	.90
Absolute Muscular Endurance[e]									
Bench Press	42	15.8	3.2	16.5	3.2	0.7	0.2	3.19[c]	.90
Leg Press	38	35.9	17.7	41.2	18.6	5.3	1.3	4.08[c]	.90
Relative Muscular Endurance[e]									
Bench Press	42	15.8	3.2	16.5	3.2	0.7	0.2	3.19[c]	.90
Leg Press	38	35.9	17.7	41.2	18.6	5.3	1.3	4.08[c]	.90

[c]Significant at the $p \leq .05$ level

[d]Pounds

[e]Number of repetitions

TABLE IV

RELIABILITY AND REPRODUCIBILITY OF NEUROMUSCULAR POST-TESTS

Test	N	Day 1 $\overline{X}$	Day 1 SD	Day 2 $\overline{X}$	Day 2 SD	$\overline{X}\Delta$	SEΔ	t	r
1 RM Strength[d]									
Bench Press	42	156.1	26.7	155.2	26.4	-0.9	1.2	-0.69	.96
Leg Press	38	456.1	62.2	448.8	59.8	-7.3	2.8	-2.57[c]	.96
Absolute Muscular Endurance[e]									
Bench Press	42	18.8	3.8	18.4	3.8	-0.4	0.2	-1.93	.94
Leg Press	38	42.1	12.2	44.6	12.7	2.5	0.8	3.02[c]	.92
Relative Muscular Endurance[e]									
Bench Press	42	16.9	3.6	16.8	3.7	-0.1	0.3	-0.09	.89
Leg Press	38	36.5	12.1	37.4	11.4	0.9	0.8	1.10	.91

[c]Significant at the $p \leq .05$ level

[d]Pounds

[e]Number of repetitions

leg press showed nonsignificant t-ratios. Similarly, nonsignificant t-ratios were found for post-tests in 1 RM strength for the bench press, absolute muscular endurance for the bench press and relative muscular endurance for both the bench press and leg press exercises. Significant t-ratios were found for the pre-tests of absolute muscular endurance for the bench press and leg press, post-tests of absolute muscular endurance for the leg press and post-tests of 1 RM strength for the leg press.

Mean changes of neuromuscular measures following treatment. The best scores of the pre- and post-tests for each subject were used in analyzing mean changes in neuromuscular data following treatment. The mean, standard deviation for the pre- and post-tests, the mean difference, the standard error of the difference, t-ratios and correlation coefficients of 1 RM strength, absolute muscular endurance and relative muscular endurance are listed in Table V. The correlation coefficients for pre- and post-test comparisons ranged from r = .74 to r = .97. The coefficient for 1 RM strength in the bench press was the highest (r = .97). This was followed by coefficients for absolute muscular endurance for the bench press (r = .92), 1 RM strength for the leg press (r = .88), absolute muscular endurance for the leg press (r = .84), relative muscular endurance for the leg press (r = .82), and relative muscular endurance for the bench press (r = .74).

Significant t-ratios were recorded between the means of pre- and post-tests for 1 RM strength in the bench press and leg press, absolute muscular endurance for the bench press and leg press and relative muscular endurance

TABLE V

MEAN CHANGES IN NEUROMUSCULAR MEASURES FOLLOWING TREATMENT

Test	N	Pre $\bar{X}$	Pre SD	Post $\bar{X}$	Post SD	$\bar{X}\Delta$	SEΔ	t	r
1 RM Strength[d]									
Bench Press	42	151.9	26.3	158.1	26.9	6.2	1.1	5.69[c]	.97
Leg Press	38	427.1	64.2	459.3	61.6	32.2	5.0	6.47[c]	.88
Absolute Muscular Endurance[e]									
Bench Press	42	16.8	3.3	19.2	3.9	2.4	0.2	10.25[c]	.92
Leg Press	38	42.1	18.6	45.6	12.4	3.5	1.7	2.03[c]	.84
Relative Muscular Endurance[e]									
Bench Press	42	16.8	3.3	17.5	3.6	0.8	0.4	2.03[c]	.74
Leg Press	38	42.1	18.6	39.0	12.0	-3.1	1.8	-1.70	.82

[c]Significant at the $p \leq .05$ level

[d]Pounds

[e]Number of repetitions

in the bench press ($p \leq .05$). A non-significant t-ratio was recorded for relative muscular endurance in the leg press ($p \leq .05$). The mean values for all variables showed an increase from pre- to post-tests with the exception of the test for relative muscular endurance for the leg press.

Summary of the Findings

Reliability and reproducibility of the anthropometric and neuromuscular data were determined by use of the Pearson product moment correlation coefficient and the dependent t-test. The correlation coefficients for all anthropometric measures were perfect positive correlations ($r = 1.00$), while test-retest correlations for pre- and post-tests ranged from $r = .74$ to $r = .97$. Pre-tests for absolute muscular endurance in the bench press and leg press and post-tests for absolute muscular endurance and 1 RM strength in the leg press showed significantly different means between the test and retest.

Analysis of mean changes in 1 RM strength for the bench press ($r = .97$) and the leg press ($r = .88$) revealed high positive correlations. Both exercises showed significant gains in 1 RM strength ($p \leq .05$) as a result of the treatment session.

Analysis of mean changes in absolute muscular endurance between pre- and post-tests yielded significant t-ratios for both the bench press and the leg press ($p \leq .05$). The correlation coefficients were highly positive for both the bench press ($r = .92$) and the leg press ($r = .84$). Analysis of the mean differences between pre- and post-tests for the variable of relative muscular endurance yielded a significant t-ratio for the bench press and a non-significant t-ratio for the leg press ($p \leq .05$).

CHAPTER V

SUMMARY, DISCUSSION AND CONCLUSIONS

Summary

The purpose of this study was to observe the effects of a set circuit weight training program on strength and muscular endurance of college age men.

Participants in the study were volunteers from weight training classes registered for the fall semester at South Dakota State University. The anthropometric variables consisted of height, weight and percent body fat. All participants were subjected to the same testing procedures and treatment.

Pre- and post-test measurements were used to determine one repetition maximum (1 RM) strength, absolute muscular endurance and relative muscular endurance for the bench press and leg press exercises. Tests were repeated prior to and following treatment.

The treatment period was seven weeks in duration and consisted of two workout sessions per week. Each workout session consisted of ten exercises with the order of the exercises remaining constant. Two sets of each exercise were completed by the subject before moving to the next station. All exercises were done in a work/rest ratio of 20 seconds/10 seconds, that is, the subjects were allowed 20 seconds to complete one set of lifting followed by a 10 second rest.

The statistical analyses used to determine reliability and reproducibility of the anthropometric and neuromuscular data were the Pearson product moment correlation coefficient and the dependent t-test.

Similar procedures were used to analyze mean differences between pre- and post-test. All statistical tests were conducted at the .05 level of probability. Comparison of pre- and post-treatment mean scores for 1 RM strength for the bench press and leg press, absolute muscular endurance for the bench press and the leg press and relative muscular endurance for the bench press resulted in means that were significantly different. The mean difference of pre- and post-treatment scores for relative muscular endurance for the leg press was not significant.

Discussion

The discussion of procedures and results of this investigation is presented as follows:

1. Discussion of the findings.
2. Discussion of the methodology.

Discussion of the findings. Numerous studies have been conducted involving weight training programs and the positive effects these programs have had on strength, muscular endurance and cardiovascular endurance (Foss, 1960; Gettman, et al, 1978; MacDougall, 1973; Conner, 1975; Mathews and Fox, 1976; Hoseth, 1967; DeLateur, 1968; O'Shea, 1966; Hansen, 1969; Wilmore, et al, 1978; and DeLorme, 1952). With the advent of the circuit weight training program, it has become a point of interest to athletes and coaches to know the extent of the effects that circuit programs have on strength and muscular endurance. This study was conducted to determine the effects of one specific circuit weight training program, the set circuit program, on these two areas of muscular development. Analysis of the pre- and post-test means for the variables of 1 RM strength and absolute muscular endurance showed significant gains for both the bench press and the leg press. These results imply that, within the limitations of this study, the set circuit program produces a positive effect on both strength and absolute muscular endurance. These findings were in agreement with the results from previous studies indicating that increased strength and muscular endurance followed training (Foss, 1960; Gettman, et al, 1978; MacDougall, 1973; Conner, 1975; Mathews and Fox, 1976; Hoseth, 1967; DeLateur, 1968; O'Shea, 1966; Hansen, 1969; Wilmore, et al, 1978; and DeLorme, 1952).

Analysis of the pre- and post-tests for the variable of relative muscular endurance produced significant results for the bench press and non-significant results for the leg press. The findings for the leg press test are similar to previous results indicating no improvement in relative muscular endurance following training (Stull and Clarke, 1970; Shaver, 1970; Clarke, 1975; and Clarke and Stull, 1970).

Discussion of the methodology. Pre-tests were given in the bench press and leg press exercises for the variables of 1 RM strength and absolute muscular endurance. Post-tests were given following treatment in the bench press and leg press for the variables of 1 RM strength, absolute muscular endurance and relative muscular endurance. Results for four subjects were not used in analyzing the leg press tests due to the inability of the instruments to measure their maximum 1 RM strength. This reduced the number of subjects used to analyze the leg press tests to 38. Accuracy of the 1 RM strength measurements was limited to the resistance intervals on the measuring instrument. The bench press and leg press stations of the universal gym were used for the 1 RM strength tests and the increments in resistance ranged from 10 to 25 pounds.

Analysis of the test-retest procedure for absolute muscular endurance pre-tests in both the bench press and leg press and the post-tests for 1 RM strength and absolute muscular endurance for the leg press yielded significant t-ratios. These differences may be accounted for by competition between subjects, self-motivation and encouragement from fellow subjects to improve upon the previous day's score.

The physical and emotional state of each individual was not controllable outside of the testing situation. The daily condition of an individual may have affected his strength or tolerance to pain which in turn would directly affect his test results.

The effort of the subjects within the testing situation could not be controlled. The literature has indicated that the overload principle must be applied if a person is to improve strength and muscular endurance. In this study there was no way to determine if each subject was reaching the point of overload.

As was mentioned in the administration of the treatment, each workout session consisted of 10 exercises with the subject completing both sets of the exercise before moving to the next activity. A work period of 20 seconds was allowed for the completion of each set, followed by a 10 second rest period. Thus, both sets of an exercise were completed in one minute and the entire workout was completed in 10 minutes. The speed in which the set circuit weight training program can be completed makes this program extremely attractive to coaches and athletes for in-season use.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1) Strength can be improved or increased by training with the set circuit program. In this study, strength was measured by employing 1 RM strength tests for the bench press and leg press. Comparison of the pre- and post-test results indicate that significant increases were found in 1 RM strength following training with the set circuit program, thus indicating that the overload principle can be applied by use of this program which in turn leads to an increase in strength.

2) Absolute muscular endurance can be improved by training with the set circuit program. It was mentioned in the literature that there exists a strong relationship between strength and muscular endurance. An increase in one of these areas is often accompanied by an increase in the other. Therefore, the increase in 1 RM strength for the bench press and the leg press would imply possible increases in muscular endurance as well. Absolute muscular endurance was measured in this study by using a modified version of Hoseth's test for muscular endurance. Analysis of the pre- and post-test means yielded significant increases for both the bench press and leg press exercises. These results indicate that the set circuit weight training program can improve absolute muscular endurance.

3) Training with the set circuit program produced mixed results for the tests of relative muscular endurance. These results were not in agreement with results from previous investigations which indicated that relative muscular endurance was unaffected by training. In this study, relative muscular endurance was measured by using a modified version of Hoseth's test for muscular endurance. Analysis of the pre- and post-tests for the leg press produced no significant difference between the means. This finding was similar with those of previous studies and implies that the application of the set circuit program has no effect on relative muscular endurance. Analysis of the pre- and post-tests for the bench press, however, produced significantly different means. This finding was in direct contrast with previous investigations which indicated that relative muscular endurance was unaffected by weight training.

BIBLIOGRAPHY

Andersen, P., and Henriksson, J. Capillary supply of the quadriceps femoris muscle of man: adaptive response to exercise. Journal of Physiology, 1977, 270, 677-690.

Barnard, R. J., Edgerton, V. R., and Peter, J. B. Effect of exercise on skeletal muscle I: biochemical and histochemical properties. Journal of Applied Physiology, 1970, 28, 762-766.

Bourne, G. H. Structure and function of muscle III. New York: Academic Press, 1960.

Brodal, P., Ingjer, F., and Hermansen, L. Capillary supply of skeletal muscle fibers in untrained and endurance trained men. American Journal of Physiology, 1977, 232, 705-712.

Clarke, D. H., and Stull, G. A. Endurance training as a determinant of strength and fatigability. Research Quarterly, 1970, 41, 19-26.

Clarke, D. H. Exercise physiology. Englewood Cliffs: Prentice-Hall, 1975.

Clarke, H. H. Application of measurement to health and physical education. Englewood Cliffs: Prentice-Hall, 1967.

Clarke, H. H., Shay, C. T., and Mathews, D. K. Strength decrement of elbow flexor muscles following exhaustive exercise. Archives of Physical Medicine and Rehabilitation, 1954, 35, 560-567.

Conner, W. P. The comparative effects of set and interval circuit weight training systems on muscular strength, cardiovascular endurance and selected anthropometric measures of college men. Unpublished doctoral dissertation, University of Northern Colorado, 1975.

Cratty, B. J. Psychology in contemporary sport: guidelines for coaches and athletes. Englewood Cliffs: Prentice-Hall, 1973.

DeLateur, G. J., Lehmann, J. F., and Fordyce, W. E. A test of the delorme axiom. Archives of Physical Medicine and Rehabilitation, 1968, 49, 245-248.

DeLorme, T. L., Ferris, B. G., and Gallagher, J. R. Effect of progressive resistance exercise on muscle contraction time. Archives of Physical Medicine, 1952, 33, 86-92.

Dobbins, B., and Sprague, K. The gold's gym weight training book. Los Angeles: St. Martin's Press, 1978.

Foss, M. L. Changes in cardiovascular condition resulting from an eight week weight training program as shown by the cameron heartometer. Unpublished masters thesis, South Dakota State University, 1960.

Gettman, L. R., Ayres, J. J., Pollack, M. L., and Jackson, A. The effect of circuit weight training on strength, cardiorespiratory function and body composition of adult men. Medicine and Science in Sports, 1978, 10, 171-176.

Goldberg, A. L., Ellinger, J. D., Goldspink, D. F., and Jablecki, C. Mechanism of work induced hypertrophy of skeletal muscle. Medicine and Science in Sports, 1975, 7, 185-198.

Goldspink, G. The combined effects of exercise and reduced food intake on skeletal muscle fibers. Journal of Cellular and Comparative Physiology, 1964, 63, 209-216.

Gollnick, P. D., Armstrong, R. B., Saubert, C. W. IV, Piehl, K., and Saltin, B. Enzyme activity and fiber composition in skeletal muscle of untrained and trained men. Journal of Applied Physiology, 1972, 33, 312-319.

Gollnick, P. D., Armstrong, R. B., Saltin, B., Saubert, C. W. IV, Sembrowich, W. L., and Shepherd, R. E. Effect of training on enzyme activity and fiber composition of human skeletal muscle. Journal of Applied Physiology, 1973, 34, 107-111.

Gordon, E. E. Anatomical and biochemical adaptations of muscle to different exercises. Journal of the American Medical Association, 1967, 201, 755-758.

Hansen, L. C. The effects of three selected weight training programs on muscular strength, endurance, girth and cardiovascular endurance. Unpublished masters thesis, South Dakota State University, 1969.

Hellebrandt, F. A. Application of the overload principle to muscle training in man. American Journal of Physical Medicine, 1958, 37, 278-283.

Henriksson, J. Training induced adaptation of skeletal muscle and metabolism during submaximal exercise. Journal of Physiology, 1977, 270, 661-675.

Hermansen, L., and Wachtlova, M. Capillary density of skeletal muscle in well trained and untrained men. Journal of Applied Physiology, 1971, 30, 860-863.

Holloszy, J. O. Adaptation of skeletal muscle to endurance exercise. Medicine and Science in Sports, 1975, 7, 155-164.

Holloszy, J. O. Biochemical adaptations in muscle: effects of exercise on mitochondrial oxygen uptake and respiratory enzyme activity in skeletal muscle. The Journal of Biological Chemistry, 1967, 242, 2278-2282.

Holmes, R., and Rasch, P. J. Effect of exercise on number of myofibrils per fiber in satorius muscle of the rat. American Journal of Physiology, 1958, 195, 50-52.

Homola, S. Muscle training for athletes. West Nyack: Parker, 1969.

Hooks, G. Application of weight training to athletics. Englewood Cliffs: Prentice-Hall, 1962.

Hoseth, P. The effectiveness of an isometric-isotonic and isotonic-isometric exercise program upon selected measures of upper body strength, muscular endurance and resting heart rate. Unpublished masters thesis, South Dakota State University, 1967.

Karpovich, P. V. Physiology of muscular activity. Philadelphia: W. B. Saunders, 1965.

MacDougall, J. D., Ward, G. R., Sale, D. G., and Sutton, J. R. Biochemical adaptation of human skeletal muscle to heavy resistance training and immobilization. Journal of Applied Physiology, 1977, 43, 700-703.

MacDougall, M. K. The effects of a timed weight training circuit program on cardiovascular endurance. Unpublished masters thesis, Springfield College, 1973.

Massey, B. H., Freeman, H. W., Manson, F. R., and Wessel, J. A. The kinesiology of weight lifting. Dubuque: Wm. Brown, 1971.

Mathews, D. K., and Fox, E. L. The physiological basis of physical education and athletics. Philadelphia: W. B. Saunders, 1976.

McMorris, R. O., and Elkins, E. C. A study of production and evaluation of muscular hypertrophy. Archives of Physical Medicine and Rehabilitation, 1954, 35, 420-426.

Morehouse, L. E., and Rasch, P. J. Scientific basis of athletic training. Philadelphia: W. B. Saunders, 1958.

Noble, L., and McCrow, L. W. Comparative effects of isometric and isotonic training programs on relative load endurance and work capacity. Research Quarterly, 1973, 44, 96-108.

O'Shea, P. Effects of selected weight training programs on development of strength and muscle hypertrophy. Research Quarterly, 1966, 37, 95-102.

Penman, K. A. Ultrastructural changes in human striated muscle using three methods of training. Research Quarterly, 1969, 40, 764-772.

Penman, K. A. Human striated muscle ultrastructural changes accompanying increased strength without hypertrophy. Research Quarterly, 1970, 41, 418-424.

Scotland, B. M. Strength, muscular endurance, and cardiorespiratory changes in college males and females as a function of training. Unpublished masters thesis, Brockport State University, 1976.

Shaver, L. G. Effects of training on relative muscular endurance in ipsilateral and contralateral arms. Medicine and Science in Sports, 1970, 2, 165-171.

Shaver, L. G. Muscular endurance in ipsilateral and contralateral arms: influence of training and inactivity. Archives of Physical Medicine and Rehabilitation, 1973, 54, 505-510.

Stull, A. G., and Clarke, D. H. High resistance, low repetition training as a determiner of strength and fatigability. Research Quarterly, 1970, 41, 189-193.

Thorstensson, A., Larsson, L., Tesch, P., and Karlsson, J. Muscle strength and fiber composition in athletes and sedentary men. Medicine and Science in Sports, 1977, 9, 26-30.

Wilmore, J. H., Parr, R. B., Girandola, R. N., Ward, P., Vodak, P. A., Barstow, T. J., Pipes, T. V., Ronero, G. T., and Leslie, P. Physiological alterations consequent to circuit weight training. Medicine and Science in Sports, 1978, 10, 79-84.

Wilmore, J. H., Parr, R. B., Vodak, P. A., Barstow, T. J., Pipes, T. V., Ward, P., and Leslie, P. Strength, endurance, bmr, and body composition changes with circuit training. Medicine and Science in Sports, 1976, 8, 59-60.

APPENDIX A

EXPERIMENTAL SUBJECT CONSENT FORM

Experiment: Observe changes in strength and muscular endurance during a seven-week training program.

Listed below is a description of the experiment in which you have been asked to participate in.

1. The purpose of this investigation is to observe the effects of a specific circuit weight training program on strength and muscular endurance.

2. All pre- and post-tests and treatment will be given during your regular weight training class sessions. No outside time will be required.

3. You will be required to participate in pre- and post-tests to determine 1 RM strength, absolute muscular endurance, and relative muscular endurance for the bench press and leg press exercises.

4. You are free to withdraw from the experiment at any time.

5. If you are participating, you are asked to refrain from any additional lifting outside of class.

6. Do you have any questions?

I have been informed of the above procedures for the study and will participate according to the above conditions.

Date: ___________ Your Signature ________________________

Your Address ________________________

Signature of Witness ____________________

Address of Witness ____________________

APPENDIX B

MEASUREMENT OF WEIGHT

<u>THE SUBJECT SHOULD BE INSTRUCTED TO:</u>

--Remove all clothing except gym shorts.

<u>THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE DIRECTIONS AND THEN SHOULD BE CERTAIN THAT:</u>

--The weight is recorded to the nearest half pound.

APPENDIX C

MEASUREMENT OF HEIGHT

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Remove his shoes.

2. Stand with back against the stadiometer.

3. Tuck chin slightly and stand erect.

4. Carefully remove himself from the stadiometer so as not to disturb the angle before the height is recorded.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE DIRECTIONS AND THEN SHOULD BE CERTAIN THAT:

1. The upper arm of the stadiometer is pressed firmly against the subject's head.

2. The upper arm of the stadiometer is horizontal.

3. The height is recorded to the nearest half centimeter.

APPENDIX D

MEASUREMENT OF BODY DENSITY THROUGH SKINFOLDS

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Stand for measurements.
2. Have feet approximately shoulder width apart.
3. Distribute weight evenly on both feet.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE DIRECTIONS AND THEN SHOULD BE CERTAIN THAT:

1. Skinfolds are measured on the right side of the body.
2. Skinfolds are grasped between the thumb and forefinger.
3. Calipers are applied approximately one centimeter below the fingers holding the skinfold.
4. Each skinfold is taken while the subject is standing.
5. The results are recorded and the measurement is repeated two more times.
6. Three measurements are taken and recorded from the following sites:
   a) Subscapula: Oblique skinfold running downward and laterally from the inferior angle of the scapula.
   b) Thigh: Vertical skinfold at the anterior midline of the thigh, halfway between the inguinal ligament and the top of the patella.

APPENDIX E

PROCEDURE FOR TESTING 1 RM STRENGTH

1. Beginning resistance for the tests will be the subject's last workout weight for that exercise.

2. The first three sets will be warm-up sets of three repetitions each. The fourth and any additional sets will be maximum lifting sets of one repetition each. The resistance for each set will be increased over that of the previous set. This will be accomplished by lowering the weight pin for the exercises one notch. This will add one additional plate to the resistance that must be lifted for the next set.

3. The subjects will be divided into groups of five. All subjects of a group will complete the first set. The order of subjects established in the first set will be maintained for all additional sets. The group will continue to lift in the order of their rotation until all members of the group have found their 1 RM strength for that exercise.

4. The maximum amount of resistance lifted through a complete range of motion one time will be recorded as your 1 RM strength for that exercise.

APPENDIX F

PROCEDURE FOR TESTING RELATIVE AND ABSOLUTE MUSCULAR ENDURANCE

1. The resistance used for the pre- and post-test absolute muscular endurance tests will be 70% of the pre-test 1 RM strength for the bench press and 80% of the pre-test 1 RM strength for the leg press. The resistance used for the post-test relative muscular endurance test will be 70% of the post-test 1 RM strength for the bench press and 80% of the post-test 1 RM strength for the leg press.

2. The subject will assume the correct position for that exercise.

3. When the subject is ready, he will do as many complete repetitions of the exercise as possible. The subject must lift through the full range of motion, that is, he must extend his arms or legs as far as possible, listen for the count of the tester, (the count will be given when the subject pauses at the end of his extension) and return the weight to its original position (the weight must be returned all the way to its resting position). The subject may continue with the next repetition after returning the weight to its original position.

4. The subject may not take rest or additional pauses after the count or when the weight has been returned to its resting place.

5. Your score will be recorded as the number of successful repetitions completed.

APPENDIX G

SAMPLE COMPUTER PROGRAM FOR SET CIRCUIT PROGRAM DATA

```
RUN NAME          SET CIRCUIT PROGRAM DATA
VARIABLE LIST     ID,ITEM01 TO ITEM20,AGE,HT1,WT1,BF1,HT2,WT2,BF2,ITEM21 TO ITEM30
INPUT MEDIUM      CARD
N OF CASES        42
INPUT FORMAT      FIXED(9(F3.0,1X),2(F2.0,1X),2(F3.0,1X),8(F2.0,1X)/T5,F2.0,1X,
                   6(F5.0,1X),4(F3.0,1X),F2.0,1X,F3.0,1X,4(F2.0,1X))
MISSING VALUES ITEM01 TO ITEM30(0)
COMPUTE           ITEM01K=ITEM01 / 2.2
COMPUTE           ITEM02K=ITEM02 / 2.2
COMPUTE           ITEM03K=ITEM03 / 2.2
COMPUTE           ITEM04K=ITEM04 / 2.2
COMPUTE           ITEM05K=ITEM05 / 2.2
COMPUTE           ITEM06K=ITEM06 / 2.2
COMPUTE           ITEM07K=ITEM07 / 2.2
COMPUTE           ITEM08K=ITEM08 / 2.2
COMPUTE           ITEM21K=ITEM21 / 2.2
COMPUTE           ITEM22K=ITEM22 / 2.2
COMPUTE           ITEM23K=ITEM23 / 2.2
COMPUTE           ITEM24K=ITEM24 / 2.2
READ INPUT DATA
T-TEST            PAIRS=ITEM01,ITEM02/ITEM03,ITEM04/ITEM05,ITEM06/ITEM07,ITEM08/
PEARSON CORR      ITEM01,ITEM02/ITEM03,ITEM04/ITEM05,ITEM06/ITEM07,ITEM08/
                  ITEM09,ITEM10/ITEM11,ITEM12/ITEM13,ITEM14/ITEM15,ITEM16/
                  ITEM17,ITEM18/ITEM19,ITEM20/HT1,HT2/WT1,WT2/BF1,BF2/
                  ITEM21,ITEM23/ITEM22,ITEM24/ITEM25,ITEM27/ITEM25,ITEM29/
                  ITEM26,ITEM28/ITEM26,ITEM30
CONDESCRIPTIVE ITEM01 TO ITEM20,AGE,HT1,WT1,BF1,HT2,WT2,BF2,ITEM21 TO ITEM30,
                  ITEM01K TO ITEM08K,ITEM21K TO ITEM24K
STATISTICS        ALL
FINISH
/*
```

APPENDIX H

WEIGHT TRAINING EXERCISES

The following are the exercises that were used in the study:

1. Bench Press: This exercise strengthens the pectoralis major, anterior deltoid and tricep muscles.

2. Leaper: The leaper exercise strengthens the quadriceps and gluteus maximus muscles.

3. Leg Press: This exercise strengthens the quadriceps and gluteus maximus muscles.

4. Hamstring Curls: The hamstring curl exercise strengthens the hamstring muscle.

5. Curls: The curl exercise strengthens the bicep and brachialis muscles.

6. Tricep Pulldowns: This exercise strengthens the tricep muscle.

7. Upright Rowing: The upright rowing exercise strengthens the biceps, brachialis, deltoid, latissimus dorsi, trapezius and teres major muscles.

8. Lat Pulls: This exercise strengthens the latissimus dorsi, posterior deltoid and bicep muscles.

9. Military Press: The military press strengthens the deltoid and tricept muscles.

10. Sit Ups: This exercise strengthens the rectus abdominis, oblique and psoas major muscles.

APPENDIX I

RAW DATA

The following are the column codes used on the raw data tables:

Column	Code
1	ID
2	Pre-test 1 for 1 RM strength - bench press
3	Pre-test 2 for 1 RM strength - bench press
4	Pre-test 1 for 1 RM strength - leg press
5	Pre-test 2 for 1 RM strength - leg press
6	Post-test 1 for 1 RM strength - bench press
7	Post-test 2 for 1 RM strength - bench press
8	Post-test 1 for 1 RM strength - leg press
9	Post-test 2 for 1 RM strength - leg press
10	Pre-test 1 for absolute muscular endurance - bench press
11	Pre-test 2 for absolute muscular endurance - bench press
12	Pre-test 1 for absolute muscular endurance - leg press
13	Pre-test 2 for absolute muscular endurance - leg press
14	Post-test 1 for absolute muscular endurance - bench press
15	Post-test 2 for absolute muscular endurance - bench press
16	Post-test 1 for relative muscular endurance - bench press
17	Post-test 2 for relative muscular endurance - bench press
18	Post-test 1 for absolute muscular endurance - leg press
19	Post-test 2 for absolute muscular endurance - leg press
20	Post-test 1 for relative muscular endurance - leg press
21	Post-test 2 for relative muscular endurance - leg press
22	Age
23	Height - Day 1
24	Weight - Day 1
25	Percent body fat - Day 1
26	Height - Day 2
27	Weight - Day 2
28	Percent body fat - Day 2
29	Pre-test for 1 RM strength - bench press, best score
30	Pre-test for 1 RM strength - leg press, best score
31	Post-test for 1 RM strength - bench press, best score
32	Post-test for 1 RM strength - leg press, best score
33	Pre-test for absolute muscular endurance - bench press, best score
34	Pre-test for absolute muscular endurance - leg press, best score
35	Post-test for absolute muscular endurance - bench press, best score
36	Post-test for absolute muscular endurance - leg press, best score
37	Post-test for relative muscular endurance - bench press, best score
38	Post-test for relative muscular endurance - leg press, best score

APPENDIX I - Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
011	185	195	485	510	205	195	535	510	15	16	070	065
021	145	145	510	460	160	160	460	460	17	18	017	025
031	170	160	000	000	170	170	000	000	13	14	000	000
041	110	110	335	335	125	110	385	385	25	28	063	063
051	135	135	485	485	145	135	535	510	16	16	038	039
061	135	125	385	385	145	145	510	485	13	13	026	025
071	135	135	360	360	145	135	360	360	16	17	054	062
081	170	170	460	485	170	170	560	535	14	15	031	045
091	170	170	435	460	185	170	485	485	12	15	030	040
101	145	145	410	410	160	145	460	435	22	18	014	017
111	135	135	335	335	135	135	385	360	19	19	035	035
121	145	135	410	410	160	160	485	485	14	15	022	024
131	145	145	335	335	145	145	335	360	21	20	033	043
141	125	125	385	385	125	135	410	410	20	21	025	035
151	125	110	335	335	135	125	360	360	18	18	040	060
161	135	135	435	435	145	145	460	460	16	17	019	024
171	135	135	360	385	135	145	435	410	19	20	053	082
181	185	185	360	360	195	185	410	410	13	14	029	043
191	205	205	000	000	205	220	000	000	15	18	000	000
201	170	170	435	460	185	185	460	485	15	18	045	030
211	170	185	535	460	170	170	535	510	12	13	021	025
221	145	170	460	460	160	170	510	485	13	13	040	040
231	205	205	485	485	220	205	510	510	15	19	040	042
241	135	125	485	485	135	135	485	510	12	13	026	030
251	135	125	410	410	135	135	435	435	13	13	028	036
261	185	185	000	000	195	195	000	000	15	17	000	000
271	110	100	360	385	110	110	435	410	26	25	023	030
281	185	185	410	385	185	185	435	410	14	16	060	075
291	135	125	410	385	135	145	410	410	13	13	021	018
301	170	170	510	460	170	170	535	560	13	13	035	041
311	195	195	560	535	195	195	535	535	15	14	016	025
321	125	125	310	360	125	125	360	335	16	16	101	101
331	135	125	435	460	145	145	460	435	14	14	032	048
341	125	135	360	335	145	135	360	385	15	14	050	051
351	100	100	360	360	100	100	435	410	15	16	046	037
361	160	170	000	000	170	170	000	000	15	16	000	000
371	145	145	460	535	145	145	560	535	17	19	020	027
381	145	145	360	335	145	145	410	410	15	16	055	060
391	160	160	410	410	160	160	410	410	15	16	025	031
401	135	135	435	435	145	145	485	460	15	15	025	026
411	145	145	435	435	145	160	485	485	17	15	030	027
421	145	160	435	485	145	160	510	510	16	18	025	040

APPENDIX I - Continued

14	15	16	17	18	19	20	21	22	23	24	25	26
17	17	15	14	59	64	65	62	18	174.0	078.0	09.22	174.0
19	20	17	15	26	28	28	34	18	180.5	099.5	37.16	180.0
17	17	18	17	00	00	00	00	18	176.5	074.0	11.43	176.5
33	29	27	26	50	62	55	43	18	174.5	068.5	11.95	175.0
18	19	18	19	38	40	37	32	18	188.0	085.0	13.46	188.0
17	16	17	16	35	39	25	26	18	185.0	091.5	23.96	185.0
19	18	20	22	68	71	65	69	19	176.5	067.5	09.14	176.0
17	18	16	16	50	48	31	38	18	181.5	102.0	17.83	181.5
16	18	14	15	50	51	36	34	18	173.0	072.0	11.39	173.0
23	20	18	16	31	30	20	23	18	172.0	082.0	17.42	172.5
21	22	15	15	33	35	22	29	18	176.5	066.0	09.77	176.5
18	17	13	12	39	42	19	21	18	192.0	090.5	13.94	192.0
22	21	23	21	50	48	40	41	19	174.0	068.5	11.79	174.0
25	26	17	19	50	50	32	33	18	167.5	053.0	08.56	167.0
20	17	14	15	45	52	40	52	18	178.0	067.0	09.50	178.0
17	15	17	17	27	31	28	30	18	176.5	069.0	12.03	176.5
20	19	21	22	65	74	42	45	19	187.0	076.0	12.86	187.0
18	19	10	12	53	50	34	38	19	167.5	059.5	09.58	167.0
20	21	17	16	00	00	00	00	18	195.5	109.0	19.84	195.5
21	19	15	17	32	35	35	39	22	173.5	079.0	12.11	173.5
16	15	12	13	39	36	28	33	18	170.0	072.0	14.06	170.0
14	13	15	14	43	45	43	36	18	171.5	074.0	12.90	171.5
19	19	16	17	48	49	40	40	18	185.5	082.0	12.42	185.5
13	12	18	15	25	29	32	34	18	178.5	091.0	18.93	178.5
14	15	14	13	29	34	30	35	18	187.0	080.5	11.79	187.0
18	19	15	14	00	00	00	00	18	186.5	091.5	10.56	186.0
29	31	29	30	40	38	29	27	19	175.0	059.0	09.50	175.0
18	18	12	13	70	67	55	61	18	181.5	079.5	14.95	181.0
18	17	16	17	31	35	30	27	18	175.0	075.0	12.98	175.5
14	13	15	15	39	44	38	36	19	181.5	071.0	09.50	182.0
15	14	14	16	27	28	30	23	19	178.5	081.0	10.21	178.5
17	15	17	16	34	58	64	52	23	189.0	077.5	11.67	198.0
17	17	17	17	50	47	43	52	19	187.5	090.0	20.25	187.5
16	16	13	17	52	50	45	45	19	172.0	061.5	08.36	172.5
20	21	19	20	30	39	29	26	18	185.5	103.0	37.83	185.0
18	18	17	14	00	00	00	00	22	179.0	097.0	19.47	179.0
23	22	18	22	30	26	31	28	18	179.5	085.5	13.50	179.5
17	17	17	18	62	65	49	45	18	174.0	062.0	10.25	174.5
16	15	18	15	34	35	40	43	18	178.5	075.5	09.73	178.0
17	18	16	14	40	39	40	37	24	169.0	081.5	26.41	169.0
21	19	16	14	32	34	28	29	20	191.0	082.0	14.26	191.0
22	21	22	21	45	47	17	23	18	181.5	088.0	18.07	181.5

APPENDIX I - Continued

27	28	29	30	31	32	33	34	35	36	37	38
078.5	09.18	195	510	205	535	16	070	17	64	15	65
100.0	37.20	145	510	160	140	18	025	20	28	17	34
173.0	11.60	170	000	170	000	14	000	17	00	18	00
069.0	12.05	110	335	125	385	28	063	33	62	27	55
086.5	13.49	135	485	145	535	16	039	19	40	19	37
091.0	23.57	135	385	145	510	13	026	17	39	17	26
067.5	09.17	135	360	145	360	17	062	19	71	22	69
103.0	17.80	170	485	170	560	15	045	18	50	16	38
072.5	11.45	170	460	185	485	15	040	18	51	14	36
082.5	17.45	145	410	160	460	22	017	23	31	18	23
066.0	09.72	135	335	135	385	19	035	22	35	15	29
091.0	14.01	145	410	160	485	15	024	18	42	13	21
067.0	11.82	145	335	145	360	21	043	22	50	23	41
053.0	08.51	125	385	135	410	21	035	26	50	19	33
067.5	09.52	125	335	135	360	18	060	20	52	15	52
070.0	12.01	135	435	145	460	17	024	17	31	17	30
074.5	12.85	135	385	145	435	20	082	20	74	22	45
060.0	09.62	185	360	195	410	14	043	19	53	12	38
108.0	19.79	205	000	220	000	18	000	21	00	17	00
078.0	12.07	170	460	185	485	18	045	21	35	17	39
071.5	14.08	185	535	170	535	13	025	16	39	13	33
074.5	12.93	170	460	170	510	13	040	14	45	15	36
081.0	12.41	205	485	220	510	19	042	19	49	17	40
092.0	18.89	135	485	135	510	13	025	16	39	18	34
081.5	11.75	135	410	135	435	13	036	15	34	14	35
090.5	10.55	185	000	195	000	17	000	19	00	15	00
059.5	09.52	110	385	110	435	26	030	31	40	31	29
079.0	14.97	185	410	185	435	16	075	18	70	13	61
073.5	13.01	135	410	145	410	13	021	18	35	17	30
072.0	09.47	170	510	170	560	13	041	14	44	15	38
081.5	12.29	195	560	195	535	15	025	15	28	16	30
077.0	11.71	125	360	125	360	16	101	17	58	17	64
090.0	20.23	135	460	145	460	14	048	17	50	17	52
062.0	08.32	135	360	145	385	15	051	16	52	17	45
102.5	37.81	100	360	100	435	16	046	21	39	20	29
097.0	19.51	170	000	170	000	16	000	18	00	17	00
086.0	13.40	145	535	145	560	19	027	23	30	22	31
062.5	10.32	145	360	145	410	16	060	17	65	18	49
074.5	09.91	160	410	160	410	16	031	16	35	18	43
081.0	26.20	135	435	145	485	15	026	18	40	16	40
082.5	14.03	145	435	160	485	17	030	21	34	16	29
089.0	18.32	160	485	160	510	18	040	22	47	22	23